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## ODOR AND ODOROUS CHEMICAL EMISSIONS FROM ANIMAL BUILDINGS: PART 2- ODOR EMISSIONS

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### Abstract

This study was an add-on project to the National Air Emissions Monitoring Study (NAEMS) and focused on comprehensive measurement of odor emissions. Odor emissions from two animal species (dairy and swine) from four sites with nine barns/rooms (two dairy barns in Wisconsin, two dairy barns and two swine rooms in Indiana, and three swine barns in Iowa) during four cycles (13-week periods) were measured. Odor samples were analyzed in three olfactometry laboratories and no significant difference was found among these laboratories. The highest ambient odor concentrations and barn odor emissions were measured for the Iowa swine site. The most intense odor and the least pleasant odor were also measured for this site. Ambient odor concentrations were the lowest for the Wisconsin dairy site. But the lowest barn odor emission rates were measured for the Indiana dairy site. Significantly higher odor emissions were measured in summer.

**KEYWORDS.** Olfactometry, odor emission, intensity, hedonic tone, dairy, swine

### INTRODUCTION

There has been growing concern over odor emissions from livestock buildings (Jacobson et al., 2008; Parker, 2008; Ni et al., 2009). In response to the growing concerns, state and federal regulatory agencies have begun to enact new air standards (Jacobson et al., 2008). However, the existing scientific research data is insufficient to develop appropriate standards, policies and recommendations to control livestock odors (Guo et al., 2006; Blanes-Vidal et al., 2009; Aneja et al., 2009).

Triangular forced-choice olfactometry is a standard method (CEN, 1999; ASTM, 2001) used to quantify odor emissions from livestock buildings (Parker et al., 2005; Guo et al., 2006; Bunton et al., 2007; Parker, 2008; Jacobson et al., 2008). The use of panelists has been considered for odor quantification because the human nose can often detect odors below the detection levels of the analytical instruments (Parker et al., 2008). Also, unlike analytical techniques (e.g., gas chromatography-mass spectrometry-olfactometer), it is possible to analyze the complete sample so that the contribution of each odorous compound in the sample is included in the analysis (Jacobson et al., 2008). There are typically three parameters used to quantify odor. The most common parameter is the odor concentration (detection threshold). Most researches report odor concentration as odor unit per cubic meter (OU/m<sup>3</sup>) (Jacobson et al., 2008). The other commonly

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used parameters are hedonic tone (offensiveness) and intensity (strength) of the odor (Parker et al., 2005, Nicell, 2009).

Several studies have investigated odor emissions from livestock buildings. Guo et al. (2006) measured odor emissions from swine production buildings and investigated the impact of ambient temperature on odor emissions. Hayes et al. (2006) measured odor emissions from intensive pig units in Ireland. Guo et al. (2007) explored daytime odor emission variations from various swine barns. Sheffield et al. (2007) reported odor concentrations downwind of Idaho dairies and heifer facilities. Parker (2008) studied odor emissions from large animal feeding operations. Lee and Zhang (2008) evaluated odor emissions from animal building dust. Blanes-Vidal et al. (2009) characterized odors released from swine slurry. Leek et al (2007) and Le et al. (2009) determined the effect of dietary crude protein on odor emissions and odor hedonic tone and intensity from swine manure. In these studies, differences between species and locations were not considered. Odor emission rates were measured from swine buildings during specific time periods and high variations have been reported in the emission rates.

This paper was part two of a five-paper series presenting results from a NRI (National Research Initiative) funded project that focused on comprehensive measurement of odor emissions. In part 1, the overall project description and overview with comparisons between olfactometry labs are presented. This paper (part 2) focuses on odor emissions as measured using olfactometry. Part 3 deals with the VOC (volatile organic compounds) emissions from the GC/MS-Olfactometry (GC/MS-O). In part 4, the correlations between the sensory (olfactometry) and chemical measurements are reported, and part 5 deals with correlations between GC/MS-O sensory data and chemical measurements.

In this study, odor emissions from two animal species (dairy and swine) from four sites with nine barns/rooms (two dairy barns in Wisconsin, two dairy barns and two swine rooms in Indiana, and three swine barns in Iowa) during four cycles (13-week periods) were measured. The objective of the study was to determine odor emission characteristics of four NAEMS sites by using common protocols and standardized olfactometry. The gained information will be used in air dispersion models and evaluation of current and future odor control technologies.

## **MATERIALS AND METHODS**

### Sample Collection

Odor samples were collected every other week from two free-stall dairy sites (two barns in Wisconsin and two barns in Indiana) and two swine sites (two finishing barns in Indiana and two gestation barns and one farrowing barn in Iowa). Eight odor samples were collected from the ventilation inlet (ambient) and the primary exhaust fan (outlet) location of each barn inside 0.05 mm thick 10-L Tedlar bags with polypropylene fittings. Tedlar bags were manufactured and cleaned by West Texas A&M and Iowa State University olfactometry laboratories. Samples were collected during four rounds. During the first 12 weeks of each round, a total of eight samples were collected every other week at each site. In the last week of each round (week 13), 24 samples were collected at one site (round 1: WI5B, round 2: IN5B, round 3: IN3B, and round 4: IA4B) and these samples were sent to all three olfactometry laboratories. The details of the sites and sample collection were described in part one (Bereznicki et al., 2010), Jacobson et al. (2008), and Jacobson et al. (2010).

### Sample and Data Analysis

Odor samples were analyzed within 30 hours of collection by a dynamic triangular forced choice olfactometer (AC'SCENT International Olfactometer, St Croix Sensory, Inc.) to determine detection threshold (odor concentration), intensity and hedonic tone. Samples were analyzed in the

University of Minnesota, Iowa State University and Purdue University olfactometry laboratories (Bereznicki et al., 2010).

*Detection threshold.* Detection threshold (odor concentration) was calculated following the ASTM (American Society for Testing and Materials) guidelines (2001). The panel detection threshold (DT) was calculated as the geometric mean of the panelist's DT and reported as odor units per cubic meter (OU/m<sup>3</sup>).

Odor emission rates (OU/s) were calculated as the product of the ventilation airflow rate (m<sup>3</sup>/s) through the building and the odor concentration (OU/m<sup>3</sup>). Ventilation air flow rate measurements were done in situ with a special fan measurement device, the Fan Assessment Numeration System (FANS) (Jacobson et al., 2008; Bereznicki et al., 2010). Odor emission rates were reported per barn area (OU/s/m<sup>2</sup>). Barn areas of the sites were as following: WI5B site 2,604 m<sup>2</sup> (barn 1) and 3,210 m<sup>2</sup> (barn 2), IN5B site 13,688 m<sup>2</sup> (barn 1 and 2), IN3B site 732 m<sup>2</sup> (room 1 and 2), and IA4B site 2150 m<sup>2</sup> (barn 1 and 2) and 138.5 m<sup>2</sup> (barn 3).

*Intensity.* Odor panelists were asked to rate the intensity of the odor using a 0 to 5 numerical scale where 0: no odor, 1: barely perceivable, 2: faint but identifiable, 3: easily perceivable, 4: strong, and 5: repulsive. The arithmetic average of intensity was calculated for each panel.

*Hedonic tone.* Hedonic tone was determined using a scale of -4 to +4, with -4 being very unpleasant, 0 being neutral, and +4 being very pleasant. The arithmetic average of hedonic tone was calculated for each panel.

To show seasonal changes, odor concentrations, emission rates, intensity and hedonic tone data were calculated per season. Seasons were defined as the following: winter (4 times from 12/4/07 to 1/31/08 and 4 times from 1/20/09 to 2/24/09), summer (4 times from 7/28/08 to 9/9/08), spring (4 times from 3/26/08 to 5/29/08 and 5 times from 3/10/09 to 5/7/09) and fall (4 times from 10/22/08 to 12/9/08).

#### Statistical Analysis

Statistical analyses were conducted using JPM software version 8.0.1 from SAS (SAS Institute Inc, Cary, NC). Data was log transformed and log transformed data had a normal distribution.

*Comparison of olfactometry laboratories.* Analysis of Variance (ANOVA) was performed using location and olfactometry laboratory (MN, IN, and IA labs) as main effects. There were a total of 13 locations at four sites (ambient, barn 1, and barn 2 at WI5B and IN5B sites, ambient, room 1 and room 2 at IN3B site and ambient, barn 1, barn 2, and barn 3 at IA4B site). The interaction between location and olfactometry laboratory was also analyzed. Significance of the main effects was determined at the 5% level.

*Comparison of ambient and barn data.* Averages of ambient measurements were calculated for each sampling. Barn data was standardized by subtracting ambient measurements from the barn measurements for each sampling. Averages of standardized barn data were calculated for each measurement.

No significant difference was found between three olfactometry laboratories so all the data was treated as they were analyzed in the same laboratory. However, significant interaction was found between location and laboratory. While comparing averages of ambient and barn data this interaction was taken into account and Tukey's Honestly Significant Difference (HSD) was calculated using the following equation:

$$HSD = \frac{q(\text{number of groups}, df_{\text{error}})}{\sqrt{2}} \sqrt{\frac{\sigma_a^2 + \sigma^2/n_{r1}}{n_{b1}} + \frac{\sigma_a^2 + \sigma^2/n_{r2}}{n_{b2}}}$$

Where;

$\sigma_a^2$ : variance between location and laboratory interaction

$\sigma_a$ : variance within location and laboratory interaction

$n_{ri}$ : number of replicates

$n_{bi}$ : number of measurements (excluding replicates) for each season/species/site/barn

q: studentized range statistic

$df_{error}$ : error degrees of freedom

Number of groups: 4 seasons, 2 species (dairy and swine), 4 sites (WI5B, IN5B, IN3B, and IA4B), and 9 barns (2 barns/rooms at WI5B, IN5B and IN3B sites and 3 barns at IA4B site).

Ambient data was analyzed using seasons, species, and species/sites (sites are nested within species) as main effects. Barn data was analyzed using seasons, species, species/sites and species/sites/barn (barns or rooms are nested within sites and sites are nested within species) as main effects.

## RESULTS AND DISCUSSION

### Comparison of Ambient Data

Average ambient odor concentrations of the sites were shown in Figure 1. No significant difference was found among four seasons but significant differences were found between species and sites. Odor concentrations from swine sites were found to be significantly higher than dairy sites. The highest odor concentrations were measured at IA4B (swine) site, which was followed by IN3B (swine), IN5B (dairy) and WI5B (dairy) sites (Figure 1).

### Comparison of Barn Data

Average barn odor concentrations ( $OU/m^3$ ) and emission rates ( $OU/s/m^2$ ) of the sites during four seasons were shown in Tables 1 and 2. Average hedonic tone and odor intensity values were given in Tables 3 and 4. Significant differences were found in emission rates ( $OU/s/m^2$ ) between seasons, species, sites, and barns/rooms.

*Seasons.* The highest odor concentrations were measured in spring except the farrowing barn of the Iowa site (Table 1). However, the highest odor emission rates ( $OU/s/m^2$ ) were measured in summer. Summer emissions were significantly higher than spring, fall and winter emissions. Spring emissions were significantly higher than fall and winter emissions. The lowest emission rates were measured in winter. Average hedonic tone and intensity values were similar in all seasons (Tables 3 and 4).

*Species.* Significantly higher emissions ( $OU/s/m^2$ ) were measured at swine sites (IN3B and IA4B) compared to dairy sites (WI5B and IN5B) (Table 2). Hedonic tone values were lower (less pleasant) and intensity values were higher (more intense odor) at swine sites (Tables 3 and 4).

*Sites and barns.* Odor emissions from barns/rooms 1 and 2 at each site showed similar trends (Figure 2) although some significant differences were found between barns/rooms. At the IA4B site, odor emissions of barn 3 were significantly lower compared to barn 1 and 2 emissions (Figure 2 and Tables 1 and 2). This was expected since barn 3 was a farrowing barn that has lower animal densities compared to the other two gestation sow barns.

When sites were compared, significantly higher odor emissions ( $OU/s/m^2$ ) were measured for the IA4B (swine) site. Odor emissions of the IN3B (swine) site were significantly higher than the WI5B and IN5B sites. The significantly lowest odor emissions were measured at IN5B site. These findings can be supported by hedonic tone and intensity values. Hedonic tone values were the

lowest (least pleasant) at IA4B site and highest at IN5B site. Intensity values were the highest at IA4B site and lowest at IN5B site.

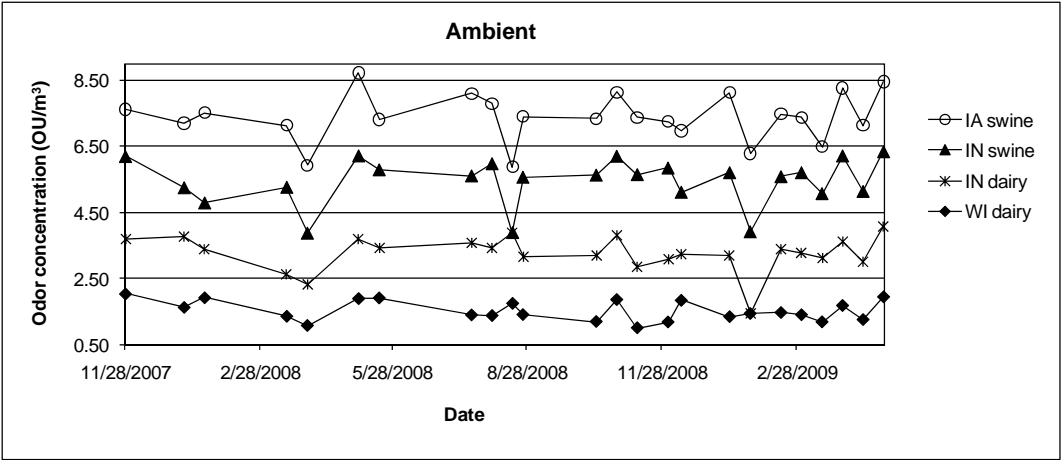


Figure 1. Average ambient odor concentrations of the sites. For clarification purpose, odor concentrations are shown in logarithmic scale.

Table 1. Average barn odor concentrations (OU/m <sup>3</sup> ) of the sites during four seasons					
Sites	Winter	Summer	Spring	Fall	Average
W15B (barn 1/2)	313.0/204.1	178.8/150.7	284.8/292.6	656.1/305.4	298.3
IN5B (barn 1/2)	145.2/150.4	185.6/189.2	208.0/148.8	169.4/127.1	165.5
IN3B (room 1/2)	795.3/1324.9	1876.4/1387.8	995.4/1138.2	912.3/1576.2	1,250.9
IA4B (barn 1/2/3)	3520.3/4556.2/ 1237.0	3569.2/2392.0/ 1237.1	4749.0/3579.1/ 962.8	3101.5/2243.0/ 1239.1	2,698.8
Average	1,361	1,241	1,373	1,147	

Table 2. Average barn odor emissions (OU/s/m <sup>2</sup> ) of the sites during four seasons					
Sites	Winter	Summer	Spring	Fall	Average
W15B (barn 1/2)	3.93/2.08	20.48/14.46	8.93/7.74	9.65/4.84	9.0
IN5B (barn 1/2)	2.21/2.45	3.69/3.88	7.06/8.63	2.96/1.42	4.0
IN3B (room 1/2)	2.97/5.09	42.18/67.22	5.63/6.51	7.27/14.52	18.87
IA4B (barn 1/2/3)	17.45/14.33/ 10.15	89.81/82.73/ 25.15	66.18/38.05/ 8.86	34.45/25.86/ 5.02	34.83
Average	6.77	38.89	17.56	11.78	

Table 3. Average barn hedonic tone values of the sites during four seasons					
Sites	Winter	Summer	Spring	Fall	Average
W15B (barn 1/2)	-1.3/-1.3	-1.4/-1.4	-1.2/-1.1	-2.2/-2.6	-1.62
IN5B (barn 1/2)	-1.4/-1.5	-1.4/-1.4	-1.5/-1.6	-1.6/-1.5	-1.5
IN3B (room 1/2)	-2.2/-2.2	-2.1/-2.1	-2.0/-1.9	-1.8/-2.1	-2.0
IA4B (barn 1/2/3)	-2.7/-2.7/ -2.3	-2.3/-2.5/ -2.1	-2.9/-2.5/ -2.4	-2.2/-2.6/ -2.5	-2.5
Average	-2.00	-1.89	-1.89	-2.11	

Table 4. Average barn intensity values of the sites during four seasons					
Sites	Winter	Summer	Spring	Fall	Average
W15B (barn 1/2)	2.8/2.6	2.1/2.1	2.4/2.3	1.9/2.4	2.33
IN5B (barn 1/2)	2.1/2.2	1.7/1.7	1.8/1.9	1.8/1.8	1.88
IN3B (room 1/2)	2.4/2.4	2.4/2.0	2.6/2.2	2.7/2.8	2.44
IA4B (barn 1/2/3)	3.2/3.1/ 2.7	3.3/3.0/ 3.0	3.1/2.8/ 2.6	3.3/3.1/ 2.8	3.00
Average	2.61	2.37	2.41	2.51	

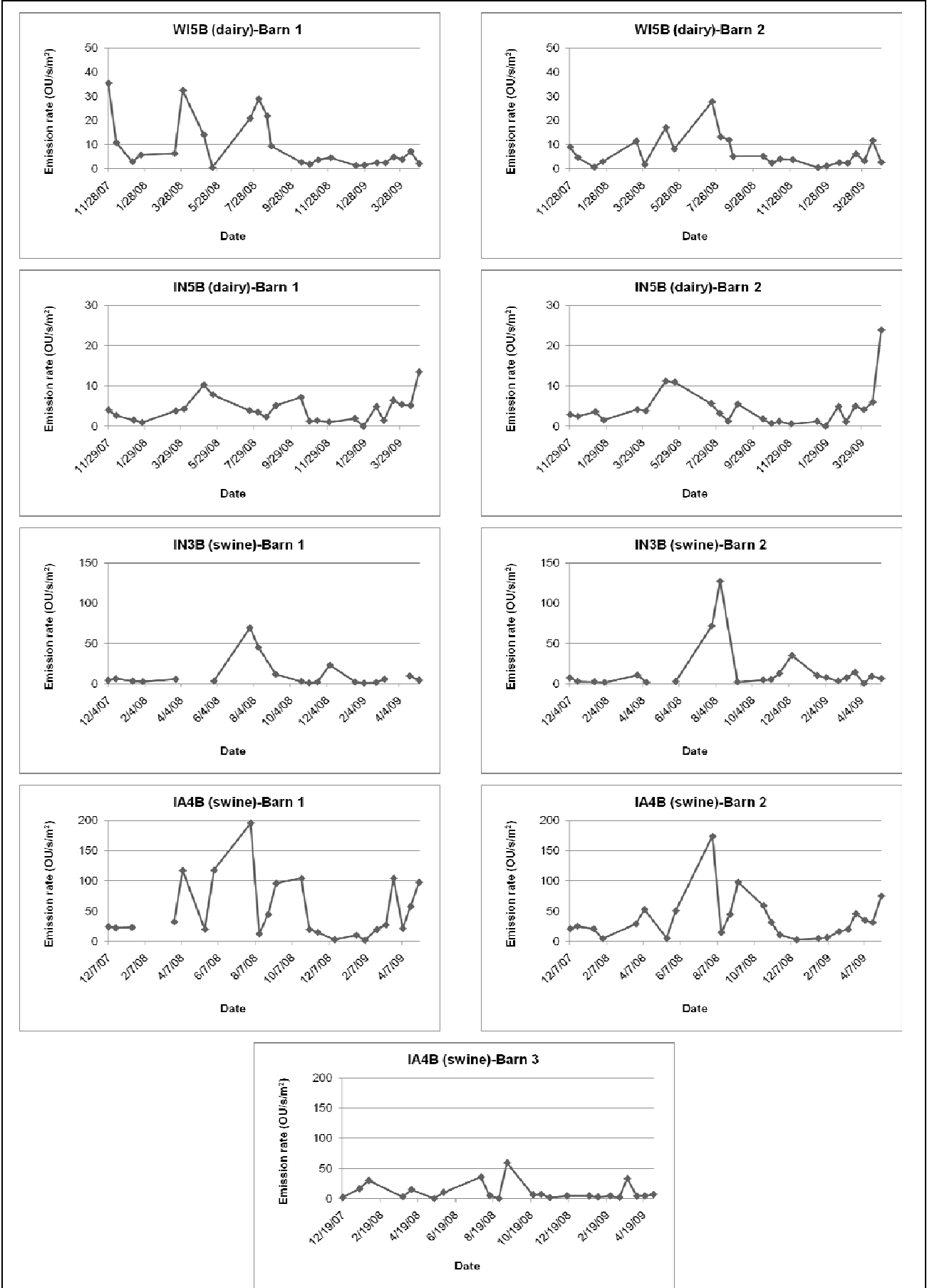


Figure 2. Odor emission rates (OU/s/m<sup>2</sup>) of the sites (broken lines show missing data points).



## CONCLUSION

The following conclusions were drawn from this research:

1. No significant difference was found between three olfactometry laboratories (University of Minnesota, Iowa State and Purdue University).
2. The highest ambient odor concentrations were measured for the IA4B (swine) site and the lowest concentrations were measured for the WI5B (dairy) site.
3. The highest odor emissions (odor unit/s/m<sup>2</sup> barn area) were measured for the IA4B site. The lowest hedonic tone (least pleasant) and the highest intensity (most intense) values were also measured for this site.
4. The lowest odor emissions, highest hedonic tone (more pleasant) and lowest intensity values were measured for the IN5B dairy site.
5. Significantly higher odor emission rates were measured in summer. This was followed by spring (except for barn 3 at IA4B), fall and winter.

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